ALASKA FEDERAL OFFSHORE
Descriptions of Geologic Plays

1995 National Resource Assessment

U.S. Minerals Management Service

GULF OF ALASKA ASSESSMENT PROVINCE

(John Larson and Gary Martin)

The Gulf of Alaska assessment province is divided into six geologic plays that reflect the tectonic and stratigraphic histories of the diverse tectonic terranes that underlie the Gulf of Alaska shelf. These plays are: (1) the Middleton fold and thrust belt; (2) the Yakataga fold and thrust belt; (3) the Yakutat shelf - base of Yakataga Formation; (4) the Yakutat shelf - Kulthieth Formation; (5) the Southeast Alaska shelf subbasin; and (6) the Subducting terrane. All of the known potential source rocks and reservoir rocks in these plays are Tertiary in age.

Play 1 (UAGA0101[1]). Middleton Fold and Thrust Belt Play: This play encompasses the offshore area extending west from the Kayak zone to approximately 149 degrees W. longitude. Traps are primarily asymmetric anticlinal closures formed on the upthrown sides of high-angle thrust or reverse faults during the late Neogene to Pleistocene. Reservoir objectives consist of sandstones in the lower part of the glaciomarine, late Miocene to Pleistocene Yakataga Formation, and sandstones locally developed in the underlying Oligocene to early Miocene Sitkinak Formation. Potential source rocks are the Sitkinak Formation (marginally mature to thermally immature) and the thermally mature Eocene Sitkalidak Formation. Both formations consist of deltaic to nonmarine sequences characterized by poor to marginal organic richness and gas-prone kerogen. The Tenneco Middleton Island State No. 1 well tested a structure in this play without recovering producible hydrocarbons.

Play 2 (UAGA0201). Yakataga Fold and Thrust Belt Play: This play extends from the Kayak zone eastward to the Pamplona zone. Potential traps are primarily areally extensive, fault-bounded anticlinal structures of Pliocene and younger age, with some stratigraphic traps possibly formed adjacent to the structures. The most prospective reservoir objectives within drillable depths are sandstones of the lower Yakataga Formation, up-dip sandstone pinchouts within the Yakataga Formation, and locally developed sandstones in the

[1]*The “UA” Code is the "Unique Assessment Identifier" for each play, and is the principal guide to GRASP data files.*

upper part of the underlying Poul Creek Formation siltstone sequence. Two potential source rock systems are known: 1, Eocene rocks of the nonmarine to deltaic Kulthieth Formation and its deeper marine equivalent facies; and 2, middle to upper Miocene rocks of the upper Poul Creek Formation. Oil has been generated at several onshore locations, including oil produced at Katalla from 1901 to 1932. However, the organically richest Miocene interval is mainly thermally immature offshore, and the Eocene source rocks are mature there only when deeply buried. Ten exploratory wells have tested several of the larger structures in this play and failed to discover recoverable hydrocarbons.

Play 3 (UAGA0401). Yakutat Shelf - Basal Yakataga Formation Play : This play encompasses the area from the Pamplona zone southeastward to just west of Cross Sound. There are a few large structural highs mapped in the area, but traps are mainly inferred to be stratigraphic and structural/stratigraphic in nature. These traps contain reservoir sandstones of the basal Yakataga and uppermost Poul Creek Formations, and consist of up-dip pinchouts, basement onlap, lateral facies transitions, and up-dip truncations against normal faults. The source rocks are the same as in the Yakataga fold and thrust belt play. Source intervals are deeply buried with moderate to relatively high thermal maturity in the northwest and are shallower with decreasing maturity to the south and east. The ARCO OCS Y-0211 (Yakutat No. 1) well tested the largest mapped structure in the play area, and recorded minor oil shows.

Play 4 (UAGA0501). Yakutat Shelf - Kulthieth Sands Play : This play underlies play 3 (Yakutat shelf - Basal Yakataga Formation) and is confined to the Eocene Kulthieth Formation. It has the same northwestern limit as the overlying play, but does not extend as far southeast. Trapping mechanisms are similar to those of the overlying play, but with additional potential for unconformity and stratigraphic traps along the southeast margin and for fault traps in the southeastern corner of the area. Potential source rocks consist of somewhat gas-prone shallow marine deltaic to basinal marine sediments in the lower part of the Kulthieth Formation and its equivalents. Relatively thick reservoir sands occur higher in the Kulthieth Formation. The ARCO OCS Y-0211 (Yakutat No. 1) well encountered minor oil and gas shows in the Kulthieth sandstones.

Play 5 (Not Quantified). Southeast Alaska Shelf Subbasin Play : Most of the southeast Alaska shelf is not prospective for hydrocarbons because total sedimentary thicknesses there are generallly less than 2,000 feet, too thin for effective hydrocarbon accumulation. The southeast Alaska shelf subbasin is an exception to this, consisting of a structurally isolated, fault-related subbasin about 35 miles wide and 65 miles long. It lies west of Prince of Wales Island and contains up to 20,000 feet of probable Cenozoic sediments that overlie metamorphic and low-grade metamorphic Mesozoic and Paleozoic basement rocks. Thermal maturity for hydrocarbon generation is possible in the central portion of the subbasin at depths below 13,500 feet.

Equivalent sedimentary rocks are lacking onshore in the immediate area. The nearest

OIL AND GAS ENDOWMENTS OF GULF OF ALASKA SHELF PLAYS

Risked, Undiscovered, Conventionally Recoverable Oil and Gas

PLAY NO.	PLAY NAME (UAI * CODE)	OIL (BBO)			GAS (TCFG)		
		F95	MEAN	F05	F95	MEAN	F05
1.	Middleton Fold and Thrust Belt (UAGA0101)	0.000	0.013	0.074	0.000	0.456	2.700
2.	Yakataga Fold and Thrust Belt (UAGA0201)	0.000	0.122	0.415	0.000	0.805	2.677
3.	Yakutat Shelf-Basal Yakataga Fm. (UAGA0401)	0.000	0.111	0.313	0.000	0.669	1.937
4.	Yakutat Shelf-Kulthieth Sands (UAGA0501)	0.000	0.308	0.778	0.000	1.967	5.397
5.	Southeast Alaska Shelf Subbasin	Not Quantified Owing to Assessed High Risk					
6.	Subducting Terrane (UAGA0701)	0.000	0.076	0.222	0.000	0.282	0.926
	FASPAG AGGREGATION	***0.183***	***0.630***	***1.434***	***0.937***	***4.180***	***10.589***

* *Unique Assessment Identifier, code unique to play.*

sedimentary rocks that are probably equivalent to the southeast Alaska shelf subbasin strata are in the Neogene age Skonun Formation. These rocks occur on Queen Charlotte Island and in the offshore Queen Charlotte basin, over 150 miles to the southeast in southwestern British Columbia. Skonun strata have favorable potential for reservoir rocks in the southern part of the Queen Charlotte basin, where they overlie potential source rocks of Mesozoic age. However, 14 exploratory wells have been drilled there with no producible hydrocarbon discoveries. In addition, Skonun lithofacies become increasingly nonmarine and gas-prone to the north and west in the direction of the southeast Alaska shelf subbasin, indicating poor source rock potential for the subbasin play. The overall likelihood of hydrocarbon accumulations in the southeast Alaska shelf subbasin is presently judged to be too low to justify further evaluation.

Play 6 (UAGA0701). Subducting Terrane Play : This play is located in the offshore area surrounding Kayak Island. In this area, Eocene to Miocene sedimentary rocks of the lower part of the Tertiary section on the Yakutat terrane are apparently being subducted along the Kayak zone, where underthrusting proceeds to the north and west beneath the basement rocks, i.e., the deformed Orca Group metasediments. Oil and gas in seeps that occur along the onshore extension of the Kayak zone at Katalla are thought to originate at depth in the area, generated from subducted Poul Creek and Kultheith Formation source rocks and then migrated upward along fractures and fault surfaces.

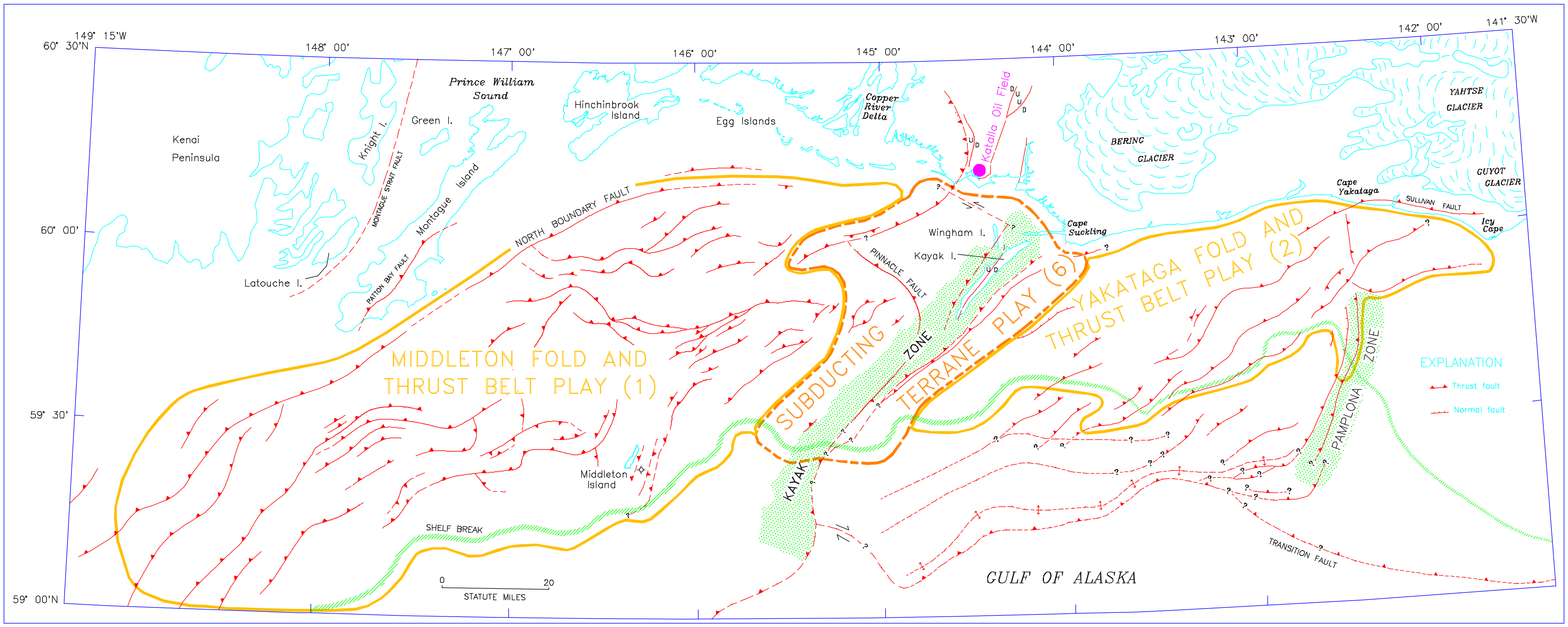
Traps in this play are likely to consist of extensively folded and faulted structures similar to those exposed onshore. Hydrocarbon accumulations might also occur in up-dip stratigraphic/structural traps along the southeast margin of the play. Potential reservoir rocks are Kulthieth and Yakataga Formation sandstones. Fracture-porosity reservoirs can also be inferred because oil was produced from fractured shales and siltstones of the Poul Creek Formation in the abandoned Katalla field onshore.

The information in this section is largely developed and/or adapted from material presented in Risely and others (1992).

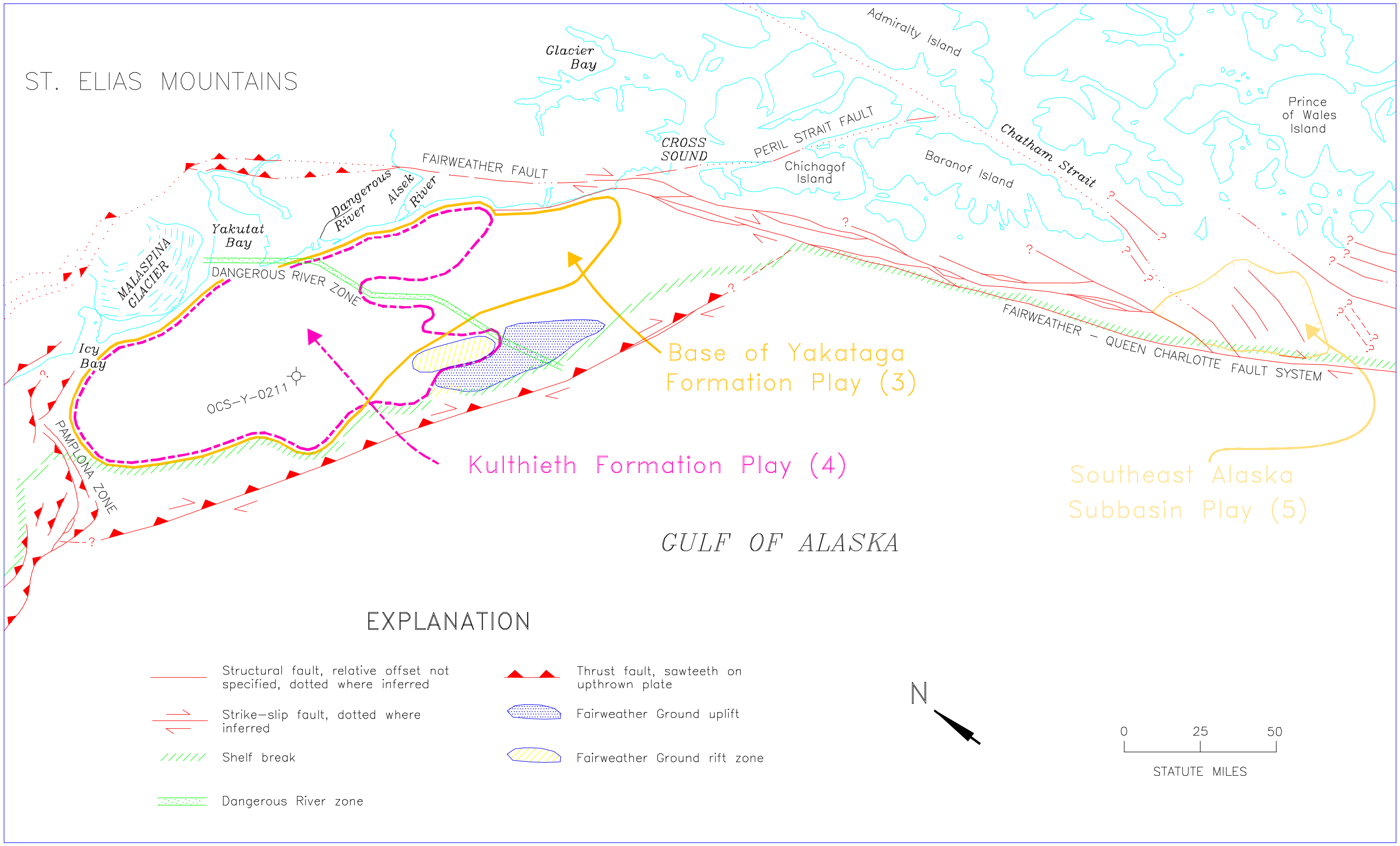
REFERENCES CITED

Risley, D.E., Martin, G.C., Larson, J.A., Lynch, M.B., Flett, T.F., and Horowitz, W.L., 1992: Geologic report for the Gulf of Alaska planning area, Turner, R.F., ed., U.S. Minerals Management Service OCS Report MMS 92-0065, 302 p., 130 figs., 9 appendices.

GULF OF ALASKA SHELF - MAP OF PLAYS 1, 2, AND 6



GULF OF ALASKA SHELF - MAP OF PLAYS 3, 4 AND 5



EXPLANATION OF DATA TABLES FOR GULF OF ALASKA SHELF ASSESSMENT PROVINCE

<u>RESULTS</u>

LOG-N PARAMS (PORE)	Key mathematic parameters that describe log-normal probability distributions for volume of hydrocarbon-bearing rock, in acre-feet, for each play as reported in the **PORE** module of **GRASP**.
mu	Natural logarithm of F50 value of log-normal distribution for volume of hydrocarbon-bearing rock, or "μ", for the subject play. **mu** = ln F50. [Note: distribution **mean** = $e^{(mu + 0.5[sig.\ sq.])}$.]
sig. sq.	The variance of the log-normal distribution for volume of hydrocarbon-bearing rock, or "σ^2", for the subject play. **sig. sq.** = $\{\ln [0.5((F50/F16)+(F84/F50))]\}^2$.
N (MPRO)	Number of hydrocarbon pools calculated for the plays by the **MPRO** module of **GRASP** from inputs for probability distributions of prospect numbers and geologic chances of success (approximately the product of play and prospect chances of success) . The maximum (**Max**) number of pools for each play was entered into the **MONTE1** module of **GRASP** to fix the number of pools aggregated to calculate play resources.
Reserves	Sums of recoverable oil and gas volumes for pools within the play, including both proven and inferred reserve categories. A "prop" entry indicates that the reserve data are proprietary.
BCF	Billions of cubic feet of gas, recoverable, at standard (surface) conditions (here fixed at a temperature of 60° Fahrenheit or 520° Rankine, and 14.73 psi atmospheric pressure).
MMB	Millions of barrels of oil, recoverable, at standard (surface) conditions.
Undiscovered Potential	Risked, undiscovered, conventionally recoverable oil and gas resources of the play, here reported at **Means** of probability distributions.

EXPLANATION OF DATA TABLES FOR GULF OF ALASKA SHELF ASSESSMENT PROVINCE

Mean Pool Sizes of Ranks 1 to 3	Unrisked (or conditional) mean volumes of recoverable oil and gas in the three largest pools in the play.

PLAY INPUT DATA

F100.....F00	Fractiles for values within probability distributions entered to **GRASP** for calculations of play resources. Four-point distributions (F100, F50, F02, F00) generally indicate that calculations were conducted using log-normal mathematics. Eight-point distributions generally indicate that calculations were conducted using Monte Carlo mathematics. Choice of mathematic approach was in most cases the option of the assessor.
Prospect Area	Maximum area of prospect closure, or area within spill contour, in acres. Probability distributions for prospect areas were generally based on distributions assembled independently for each play from large numbers of prospects mapped with seismic reflection data.
Trap Fill	Trap fill fraction, or fraction of prospect area in which the reservoir is predicted to be saturated by hydrocarbons.
Pool Area	Areal extent of hydrocarbon-saturated part of prospect, in acres. Calculated using **PRASS**, or **SAMPLER** module of **GRASP**, to integrate input probability distributions for prospect areas and trap fill fractions.
Pay Thickness	Thickness of hydrocarbon-productive part of reservoir within pool areas, in feet. Probability distributions for prospect areas, trap fill fractions, and pay thicknesses are integrated in the **PORE** module of **GRASP**, to calculate a probability distribution for volume of hydrocarbon-bearing rock, in feet, within the play as reported above under **LOG-N PARAMS (PORE)** .

EXPLANATION OF DATA TABLES FOR GULF OF ALASKA SHELF ASSESSMENT PROVINCE

Oil Yield (Recov. B/Acre-Feet)	Oil, in barrels at standard (surface) conditions, recoverable from a volume of one acre-foot of oil-saturated reservoir in the subsurface. Oil yield probability distributions were generally calculated in a separate exercise using **PRASS** to integrate input probability distributions for porosities, oil saturations, oil shrinkage factors (or "Formation Volume Factors"), and oil recovery efficiencies.
Gas Yield (MMCF/Ac.-Ft.)	Gas, in millions of cubic feet at standard (surface) conditions, recoverable from a volume of one acre-foot of gas-saturated reservoir in the subsurface. Distributions were generally calculated in a separate exercise using **PRASS** to integrate input probability distributions for porosities, gas saturations, reservoir pressures, reservoir temperatures (in degrees Rankine), gas deviation ("Z") factors, combustible fractions (that exclude noncombustibles such as carbon dioxide, nitrogen, etc.), and gas recovery efficiencies.
Solution Gas-Oil Ratio (CF/B)	Quantity of gas dissolved in oil in the reservoir that separates from the oil when brought to standard (surface) conditions, in cubic feet recovered per barrel of produced oil.
Gas Cond. (B/MMCF)	Quantity of liquids or condensate dissolved in gas in the reservoir that separates from the gas when brought to standard (surface) conditions, in barrels recovered per million cubic feet of produced gas.
Number of Prospects.......	Probability distributions for numbers of prospects in plays, generally ranging from minimum values (F99) representing the numbers of mapped prospects, to maximum values (F00) that include speculative estimates for the numbers of additional prospects that remain unidentified (generally stratigraphic prospects, geophysically indefinite prospects, or prospects expected in areas with no seismic coverage).

EXPLANATION OF DATA TABLES FOR GULF OF ALASKA SHELF ASSESSMENT PROVINCE

Probabilities for Oil, Gas, or Mixed Pools

Oil (OPROB) Fraction of hydrocarbon pools that consist entirely of oil, with no free gas present. Typically, an undersaturated oil pool.

Gas (GPROB) Fraction of hydrocarbon pools consisting entirely of gas, with no free oil present.

Mixed (MXPROB) Fraction of hydrocarbon pools that contain both oil and gas as free phases, the gas usually present as a gas cap overlying the oil.

Fraction of Net Pay to Oil (OFRAC) When a hydrocarbon pool is modeled as a mixed case, with both oil and gas present, the fraction of pool volume that is saturated by oil in the subsurface.

Play Chance Success Probability that the play contains at least one pool of technically-recoverable hydrocarbons (that would flow into a conventional wellbore in a flow test or during production).

Prospect Chance Success The fraction of prospects within the play that are predicted to contain hydrocarbon pools, given the condition that at least one pool of technically-recoverable hydrocarbons occurs within the play.

Play Type (E-F-C) Play classification scheme.

E **Established** play, in which significant numbers of fields have been discovered, providing the assessor with data for pool size distributions and reservoirs sufficient to allow the assessor to model the play with confidence.

F **Frontier** play, where exploration activities are at an early stage. Some wells have already been drilled to test the play concept but no commercial fields have been established.

EXPLANATION OF DATA TABLES FOR GULF OF ALASKA SHELF ASSESSMENT PROVINCE

C	**Conceptual** play, hypothesized by analysts based on the subsurface geologic knowledge of the area. Such plays remain hypothetical and the play concept has not been tested.

GULF OF ALASKA

				Log-N Params.							
				PORE		N (MPRO)		Reserves		Undiscovered Potentia	
Play				Ac/Ft	Ac/Ft	No. Pools		Gas	Oil	Gas	Oil
No.	Area	UAI Code	Name	mu	sig. sq.	Mean	Max	(BCF)	(MMB)	(BCF)	(MMB)
1	Gulf of Alaska	UAGA0101	Middleton Fold and Thrust Belt	11.62	2.17	3.3	54	* *	* *	456	13
2	Gulf of Alaska	UAGA0201	Yakataga Fold and Thrust Belt	11.99	1.84	3.5	26	* *	* *	805	122
3	Gulf of Alaska	UAGA0401	Yakutat Shelf- Base of Yakataga Fm.	11.42	1.98	6.0	33	* *	* *	669	111
4	Gulf of Alaska	UAGA0501	Yakutat Shelf-Kulthieth Sands	12.09	2.05	7.3	34	* *	* *	1967	308
6	Gulf of Alaska	UAGA0701	Subducting Terrane	11.62	1.96	2.9	15	* *	* *	282	76

		MEAN POOL SIZES OF RANKS 1 TO 3											
		Pool #1		Pool #2		Pool #3		INPUT DATA					
PLAY		Gas	Oil	Gas	Oil	Gas	Oil	Prospect Area (Acres)					
No.	Name	(BCF)	(MMB)	(BCF)	(MMB)	(BCF)	(MMB)	F100	F95	F75	F50	F25	F05
1	Middleton Fold and Thrust Belt	900	25	389	11	246	7	140	1270	3560	7290	14900	41700
2	Yakataga Fold and Thrust Belt	722	111	270	42	149	24	100	1100	2700	5250	10000	27000
3	Yakutat Shelf- Base of Yakataga Fm.	471	83	186	33	106	19	100	480	1350	2800	6700	16500
4	Yakutat Shelf-Kulthieth Sands	1210	179	486	70	264	40	100	980	2600	5000	9700	26000
6	Subducting Terrane	234	56	75	18	39	10	150	690	1900	3700	7500	20000

		INPUT DATA											
PLAY		Prospect Area (Acres)			Trap Fill (Dec. Frac.)								
No.	Name	F02	F01	F00	F100	F95	F75	F50	F25	F05	F02	F01	F00
1	Middleton Fold and Thrust Belt	64400	86000	130000	0.03	0.06	0.10	0.15	0.20	0.33	0.45	0.49	0.70
2	Yakataga Fold and Thrust Belt	39000	49800	100000	0.08	0.15	0.20	0.30	0.40	0.56	0.67	0.70	0.94
3	Yakutat Shelf- Base of Yakataga Fm.	24000	33000	100000	0.08	0.15	0.20	0.30	0.40	0.55	0.67	0.70	0.95
4	Yakutat Shelf-Kulthieth Sands	38000	49000	101000	0.08	0.15	0.20	0.30	0.40	0.55	0.67	0.70	0.95
6	Subducting Terrane	30000	39000	84000	0.08	0.15	0.20	0.30	0.40	0.55	0.67	0.70	0.95

GULF OF ALASKA

PLAY		INPUT DATA													
PLAY		Pool Area (Acres)									Pay Thickness (Feet)				
No.	Name	F100	F95	F75	F50	F25	F05	F02	F01	F00	F100	F95	F75	F50	F25
1	Middleton Fold and Thrust Belt	11	143	478	1110	2580	8640	14400	20200	115000	5	28	59	100	170
2	Yakataga Fold and Thrust Belt	26	260	763	1610	3410	10000	15700	21300	99900	5	28	59	100	170
3	Yakutat Shelf- Base of Yakataga Fm.	12	133	415	915	2020	6280	10100	13900	71200	5	28	59	100	170
4	Yakutat Shelf-Kulthieth Sands	24	238	703	1490	3160	9320	14700	19900	94100	4	27	65	120	220
6	Subducting Terrane	15	165	508	1110	2430	7470	12000	16500	82700	5	28	59	100	170

		INPUT DATA														
PLAY		Pay Thickness (Feet)				Oil Yield (Recov. B/Acre-Foot)								Gas Yield (MMCF/Ac.-Ft)			
No.	Name	F05	F02	F01	F00	F100	F95	F75	F50	F25	F05	F01	F00	F100	F95	F75	F50
1	Middleton Fold and Thrust Belt	363	500	619	1844	29	61	86	110	141	200	256	425	0.046	0.137	0.226	0.322
2	Yakataga Fold and Thrust Belt	363	500	619	1844	32	72	106	139	182	267	350	609	0.088	0.267	0.450	0.646
3	Yakutat Shelf- Base of Yakataga Fm.	363	500	619	1844	34	78	115	150	196	289	378	658	0.041	0.152	0.280	0.428
4	Yakutat Shelf-Kulthieth Sands	526	760	971	3395	47	97	137	174	221	312	397	650	0.070	0.222	0.382	0.557
6	Subducting Terrane	363	500	619	1844	32	72	106	139	182	267	350	609	0.053	0.165	0.280	0.406

		INPUT DATA														
PLAY		Gas Yield (MMCF/Ac.-Ft)				Solution Gas Oil Ratio (CF/B)								Gas Cond. (B/MMCF)			
No.	Name	F25	F05	F01	F00	F100	F95	F75	F50	F25	F05	F01	F00	F100	F95	F75	F50
1	Middleton Fold and Thrust Belt	0.457	0.757	1.080	2.230	380	600	810	1010	1290	1770	2250	2760	11	19	24	28
2	Yakataga Fold and Thrust Belt	0.929	1.560	2.260	4.770	470	720	960	1190	1460	1850	2300	2850	20	35	42	52
3	Yakutat Shelf- Base of Yakataga Fm.	0.653	1.200	1.840	4.410	370	600	810	1020	1320	1900	2300	2900	20	35	42	52
4	Yakutat Shelf-Kulthieth Sands	0.812	1.400	2.040	4.460	300	520	730	960	1250	1800	2250	3000	20	35	42	52
6	Subducting Terrane	0.586	0.995	1.440	3.080	300	520	730	960	1250	1800	2250	3000	20	35	42	52

GULF OF ALASKA

PLAY		INPUT DATA											
PLAY		Gas Cond. (B/MMCF)				Number of Prospects in Play							
No.	Name	F25	F05	F01	F00	F99	F95	F75	F50	F25	F05	F01	F00
1	Middleton Fold and Thrust Belt	31	38	44	55	22	26	32	37	43	52	61	88
2	Yakataga Fold and Thrust Belt	55	68	75	100	9	11	16	19	23	30	36	54
3	Yakutat Shelf- Base of Yakataga Fm.	55	68	75	100	16	20	24	29	33	41	46	67
4	Yakutat Shelf-Kulthieth Sands	55	68	75	100	19	22	28	32	38	46	54	79
6	Subducting Terrane	55	68	75	100	7	8	10	12	14	17	20	28

PLAY		INPUT DATA						
		Probabilities for Oil, Gas, or Mixed Pools			Fraction of Net	Play	Prospect	
PLAY		Oil	Gas	Mixed	Pay to Oil	Chance	Chance	Play Type
No.	Name	(OPROB)	(GPROB)	(MXPROB)	(OFRAC)	Success	Success	E - F - C
1	Middleton Fold and Thrust Belt	0	0.9	0.1	0.10	0.18	0.48	C
2	Yakataga Fold and Thrust Belt	0	0	1	0.40	0.60	0.29	C
3	Yakutat Shelf- Base of Yakataga Fm.	0	0	1	0.35	0.65	0.31	C
4	Yakutat Shelf-Kulthieth Sands	0	0	1	0.30	0.80	0.27	C
6	Subducting Terrane	0	0	1	0.45	0.90	0.25	C

EXPLANATION OF GULF OF ALASKA SHELF PLAY SUMMARIES

This section consists of page-size compilations of graphics that summarize the results of ***GRASP*** modeling of the undiscovered, conventionally recoverable oil and gas endowments of each of the plays identified and assessed in the province. Each play summary features a plot for risked cumulative probability distributions for oil, gas, and BOE (gas in oil-equivalent barrels added to oil), a table of results, and a plot showing ranked sizes (oil and gas shown separately) of individual hypothetical pools. These three components of the play summaries are each described below.

Risked Cumulative Probability Distributions for Plays

Each play summary provides, at page top, cumulative probability distributions for risked, undiscovered endowments of conventionally recoverable oil, gas, and BOE. Oil and BOE quantities are shown in billions of barrels (B bbl). Gas quantities are reported in trillions of cubic feet (Tcf). Resource quantities are plotted against "Cumulative frequency greater than %." A cumulative frequency value represents the probability that the play resource endowment will exceed the quantity associated with the frequency value along one of the curves (fig. 0.1). Cumulative frequency values along the curves decrease as resource quantities increase. Accordingly, the cumulative frequencies, or "probabilities for exceedance," of small resource quantities are high, and conversely, the probabilities for exceedance of large resource quantities are low.

The cumulative probability distributions are risked and curves are truncated approximately at the output play chance. In most plays, the output play chance is equal to the input play chance for success. However, in plays with very small numbers of pools, the output play chance may be significantly **lower** than the input play chance for success.

The output play chance is derived from MPRO, a module within ***GRASP*** which uses inputs for geologic chance of success to convert probability distributions for numbers of ***prospects*** to probability distributions for numbers of ***pools***. The output play chance is obtained as a mathematic extrapolation to the probability at which the numbers of pools meets or exceeds zero. In plays with 5 or more pools at the mean, this probability usually equals the input play chance for success. In plays with less than 5 pools at the mean, the zero-pool probability (or output play chance) may be much less than the input play chance. Deviation between the output play chance and the input play chance is greatest in those plays with mean numbers of pools less than unity. Such highly risky plays contribute very little resources to overall province endowments.

Identification numbers beginning with "UA" in the graphics labels are codes unique to each of the plays in the ***GRASP*** data bases.

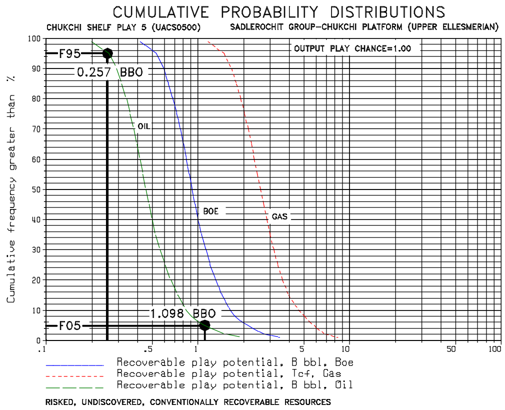
Table for Risked Play Resource Endowments

Each play summary provides, at page center, a table for risked, undiscovered play endowments of oil, gas, and BOE in billions of barrels of oil (BBO) or trillions of cubic feet of gas (TCFG). Quantities are reported at the **mean**, **F95** (a low estimate having a 95-percent frequency of exceedance), and **F05** (a high estimate having a 5-percent frequency of exceedance). Tabulated resource quantities are risked and therefore correspond to points on the cumulative probability distributions shown at page top. For plays with chances for success (play level) less than 0.95, the risked resource quantities reported at **F95** are zero.

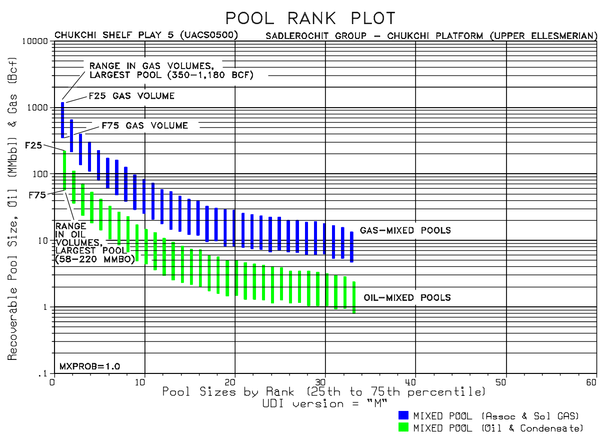
Ranked Pool Size Distributions for Plays

Each play summary provides, at page bottom, a plot showing pool sizes ranked according to size in BOE. The numbers of pools shown in the rank plots correspond to the maximum numbers of pools estimated to occur within the plays. Each pool in a pool rank plot is represented by a pair of adjoining vertical bars. The left bar of each pair represents the range (from **F75** to **F25** in the output probability distribution) of gas recoverable from the pool, and may include non-associated gas from an all-gas pool or associated gas from a gas cap and/or solution gas from oil, depending on pool type. The right bar of each pair represents the range (from **F75** to **F25**) of petroleum liquids recoverable from the same pool, and may include free oil, condensate from a gas cap, or condensate from a gas-only pool.

Volumes are shown in millions of barrels (MMbbl) of oil and billions of cubic feet (Bcf) of gas.



CHUKCHI SHELF PLAY 5 (UACS0500)			
FRACTILES	F95	MEAN	F05
GAS (TCFG)	1.478	2.993	5.823
OIL (BBO)	0.257	0.537	1.098
BOE (BBO)	0.530	1.069	2.125



The upper graph and the table report the volumes of risked, undiscovered, conventionally recoverable resources for the play. The graph, called a ***cumulative probability distribution***, shows three curves (oil, BOE, and gas) and reports the output play chance at upper right. The output play chance for Chukchi shelf play 5 is 1.0, meaning that there is a 100-percent chance that at least one hydrocarbon pool exists somewhere within the play. To illustrate how to read the graphs, dots have been placed on the ***oil*** curve at cumulative frequency values (vertical axis) of 95-percent and 5-percent. The corresponding oil quantities are 0.257 and 1.098 billions of barrels of oil. Thus, for Chukchi shelf play 5, there is a 95-percent chance that at least 0.257 billion barrels of oil are present and a 5-percent chance that more than 1.098 billion barrels are present. These same oil quantities are listed at F95 and F05 in the table.

The lower graph provides information about pool volumes and is called a ***pool rank plot***. This graph shows two sets of vertical bars, representing the quantities of oil and gas occurring ***together*** in 33 pools, the maximum number estimated to occur within this play. All pools in play 5 are modeled as mixed, that is, containing oil with a gas cap; other plays may also have all-gas or all-oil pools and show six separate commodities. Each pair of gas-oil bars in the play 5 pool rank plot shows the volume of oil in the pool and the volume of gas in the cap. The vertical bars extend across a range of possible volumes for each pool. The lower end of each bar represents the F75 resource quantity, meaning that the pool, if it exists, has a 75-percent chance of exceeding the corresponding resource quantity. Likewise, the upper end of each bar represents the F25 resource quantity. In Chukchi play 5, the largest pool offers oil volumes in the range from about 58 (F75) to 220 (F25) million barrels and gas volumes in the range from 350 (F75) to 1,180 (F25) billion cubic feet.

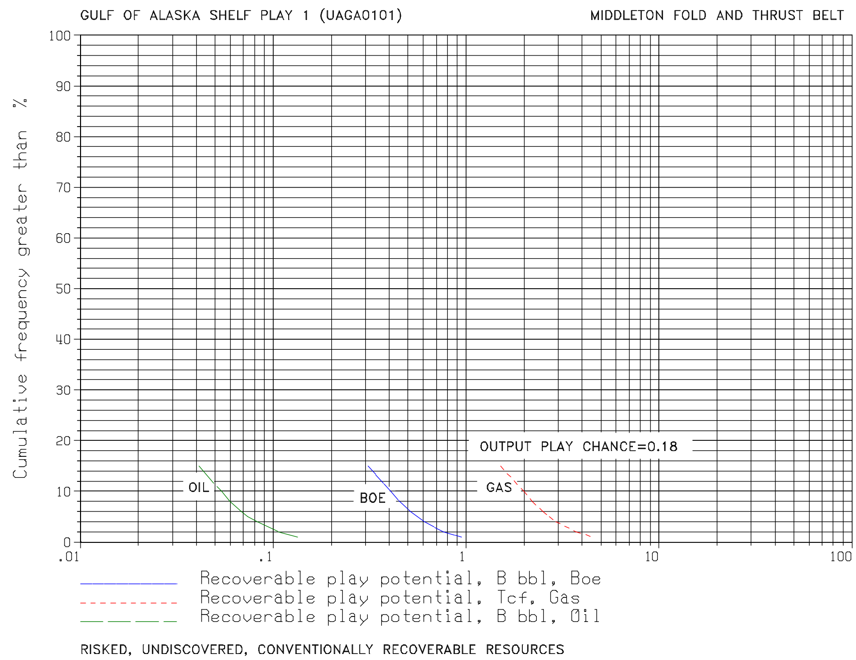
Figure 0.1: Sample play summary, Chukchi shelf play 5.

Extreme sizes outside the range between F75 and F25 volumes are not shown, but all pools offer (at low probabilities) high-side potential that may be several multiples of their median sizes (F50 or centers of vertical bars). For example, the largest pool in the pool rank plot in figure 0.1 shows F75-F25 ranges in oil volumes from 58 to 220 millions of barrels and gas volumes from 350 to 1,180 billions of cubic feet. But, these ranges do not capture the largest possible sizes of pool rank 1. This same pool has a 5-percent chance of containing over 600 million barrels of oil and 3,070 billion cubic feet of gas, or a 1-percent chance of containing over 1,140 million barrels of oil and 6,180 billion cubic feet of gas!

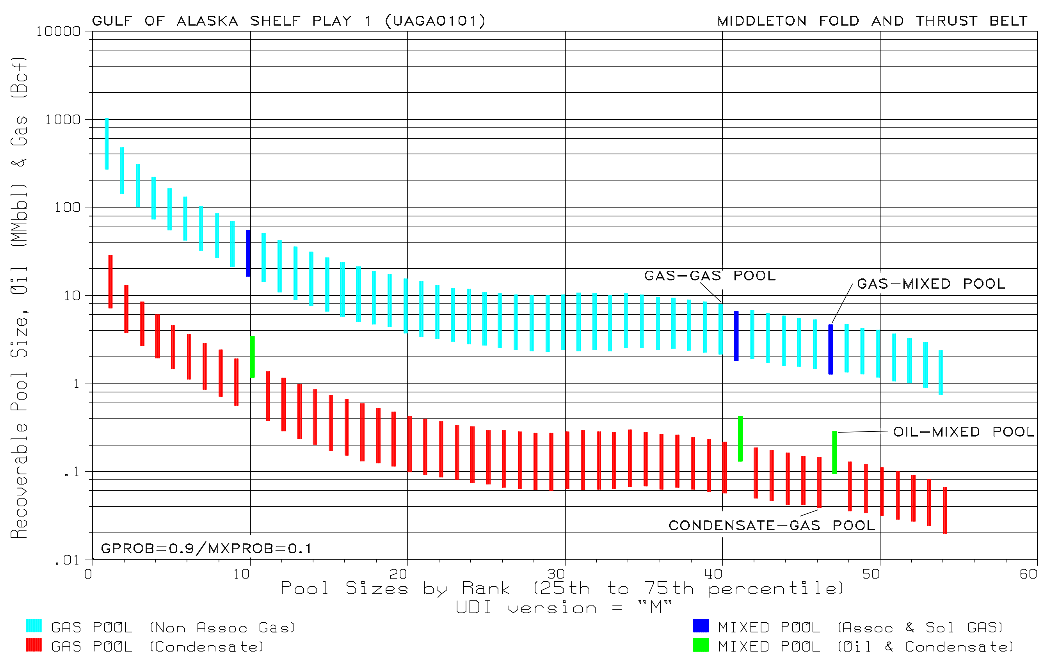
Although it might be interesting to portray the improbable yet extreme-high potential sizes of pools, choosing fractiles ranging up to F01 results in an uninformative plot where all pools nearly reach the top of the plot. For this presentation, a range based on F75-F25 values was chosen for visual clarity while still giving some impression of variance or spread.

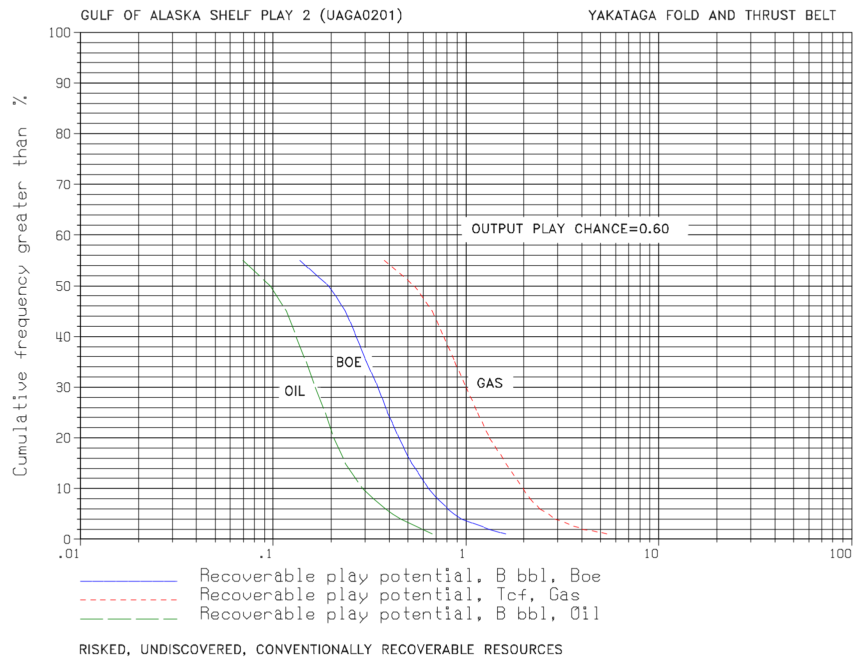
Pool volumes shown in the ranked plots are conditional upon success at the play level (i.e., a hydrocarbon pool existing ***somewhere*** within the play). The sizes of the pools posted in the rank plot have not been “risked”, or multiplied against play chance of success. Therefore, except where the play chance of success equals 1.0, the sum of the mean sizes of the pools in the rank plot will exceed the risked mean play endowment that is reported in the table at page center. In fact, several of the largest pools, or even just the largest pool, may post conditional resources exceeding the risked play endowment.

Designation of pool types (oil-only, versus oil with gas cap, versus gas-only) within the play model was controlled by three data entries. Each play was assigned probabilities for (or frequencies of) occurrence of any of three pool types within the play—“OPROB” for oil-only pools, “GPROB” for gas-only pools, and “MXPROB” for mixed (oil and gas cap) pools. As the model recognizes only these three pool types, these three probability values always sum to 1.0. The three probability values control frequency of pool type sampling during ***GRASP*** runs, and, with a random number generator in ***GRASP***, ultimately dictate the sequence of pool types that appear in the play pool rank plots. The OPROB, GPROB, and/or MXPROB values that were used in the play models are posted, as appropriate, in the lower left corner of each pool rank plot.

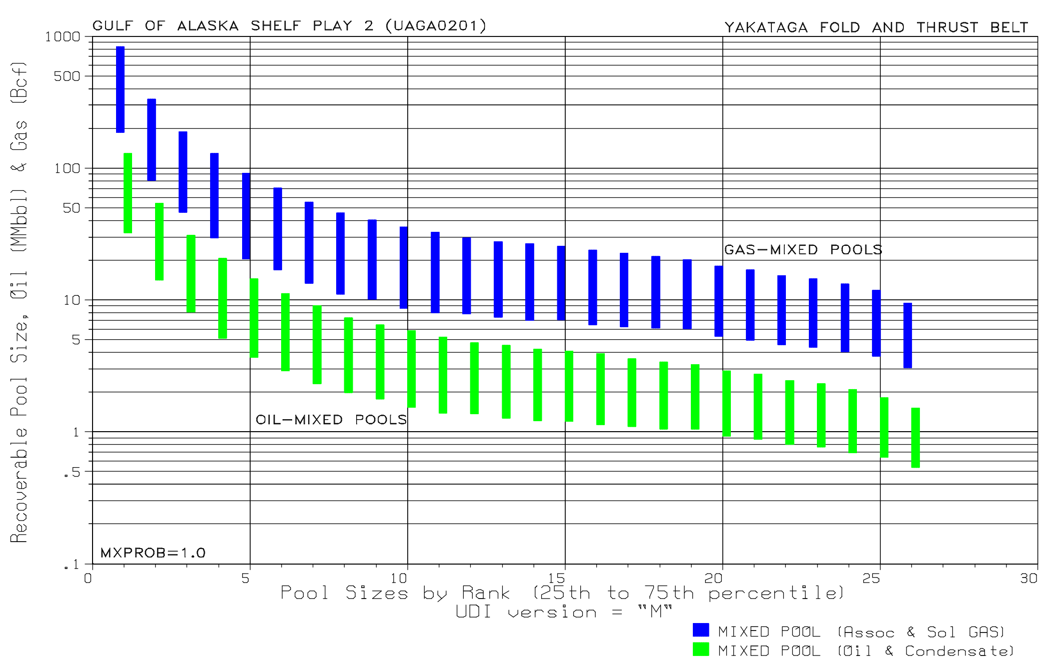


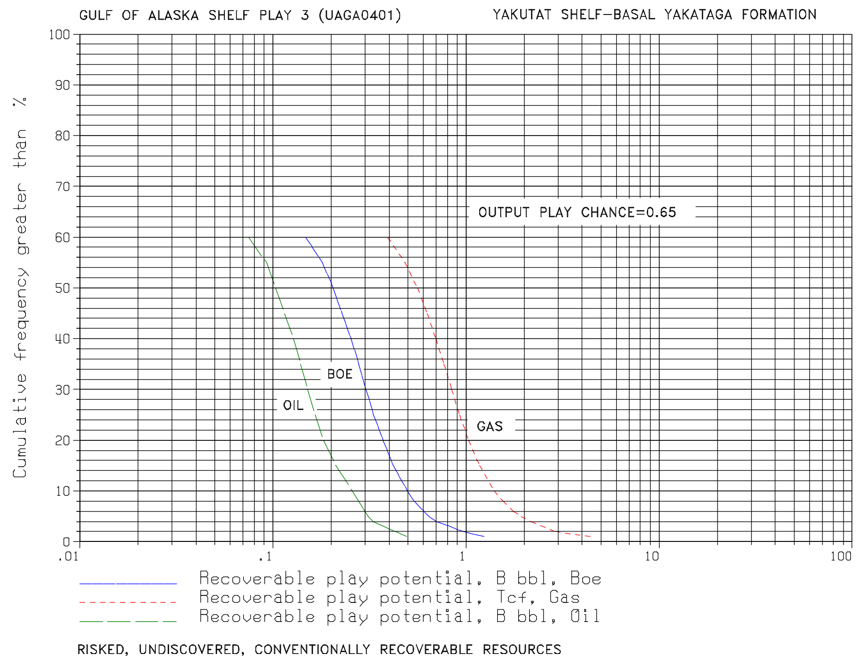
GULF OF ALASKA SHELF PLAY 1 (UAGA0101)			
FRACTILES	**F95**	**MEAN**	**F05**
GAS (TCFG)	**0.000**	**0.456**	**2.700**
OIL (BBO)	**0.000**	**0.013**	**0.074**
BOE (BBO)	**0.000**	**0.094**	**0.557**



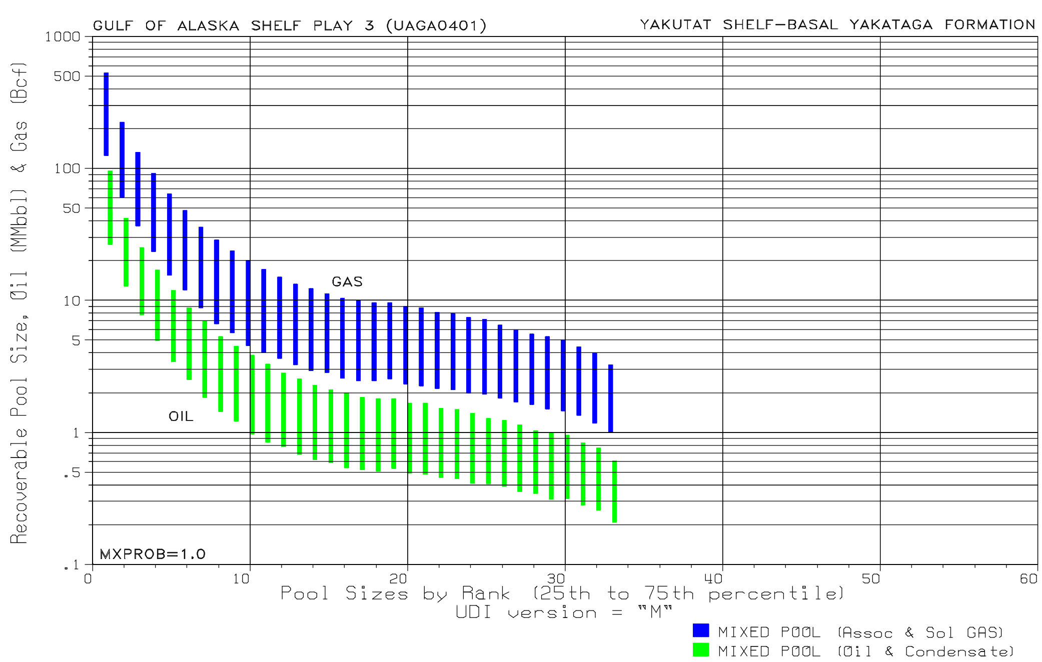


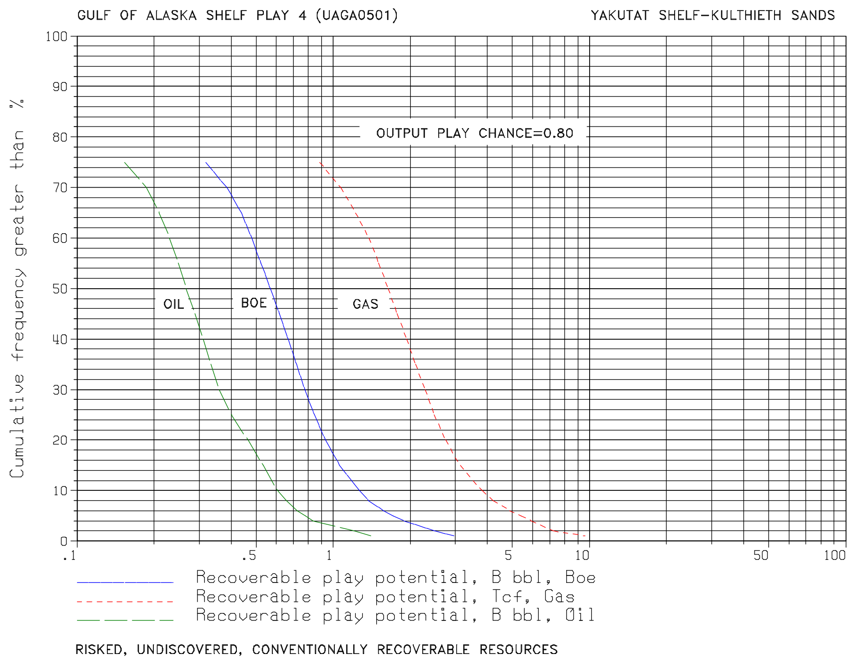
GULF OF ALASKA SHELF PLAY 2 (UAGA0201)			
FRACTILES	**F95**	**MEAN**	**F05**
GAS (TCFG)	**0.000**	**0.805**	**2.677**
OIL (BBO)	**0.000**	**0.122**	**0.415**
BOE (BBO)	**0.000**	**0.265**	**0.866**



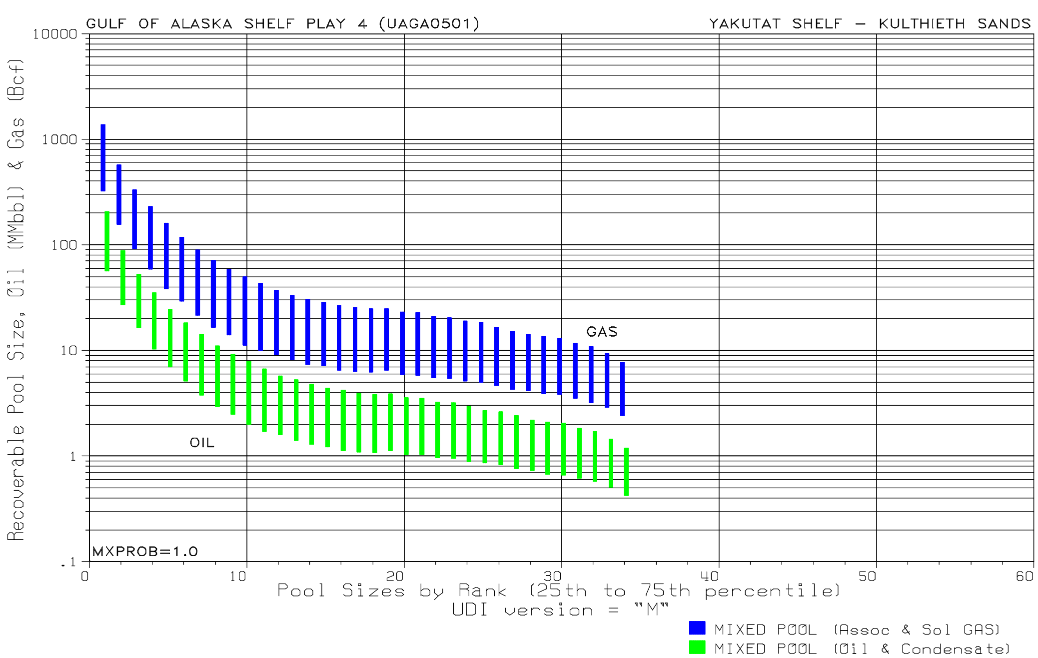


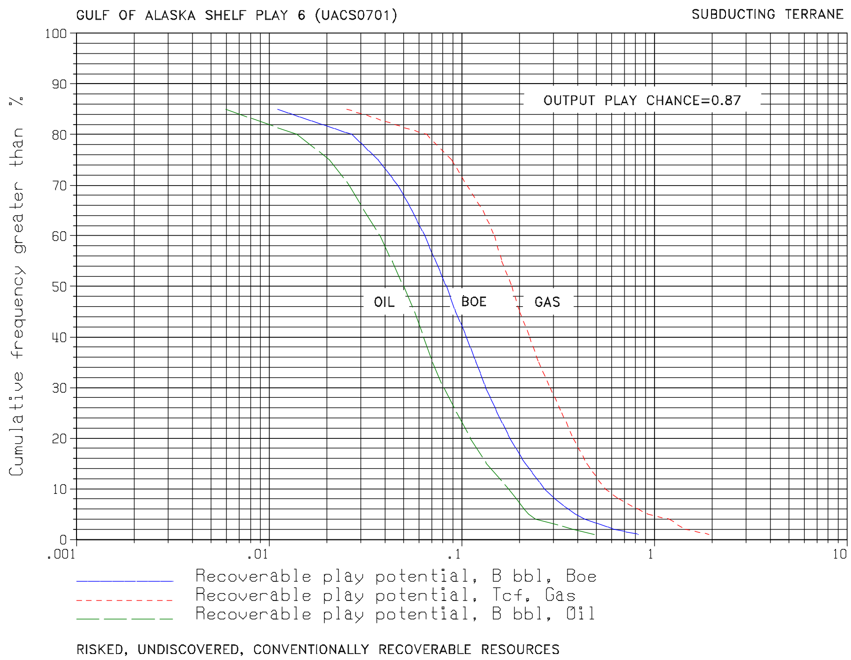
GULF OF ALASKA SHELF PLAY 3 (UAGA0401)			
FRACTILES	**F95**	**MEAN**	**F05**
GAS (TCFG)	**0.000**	**0.669**	**1.937**
OIL (BBO)	**0.000**	**0.111**	**0.313**
BOE (BBO)	**0.000**	**0.230**	**2.036**



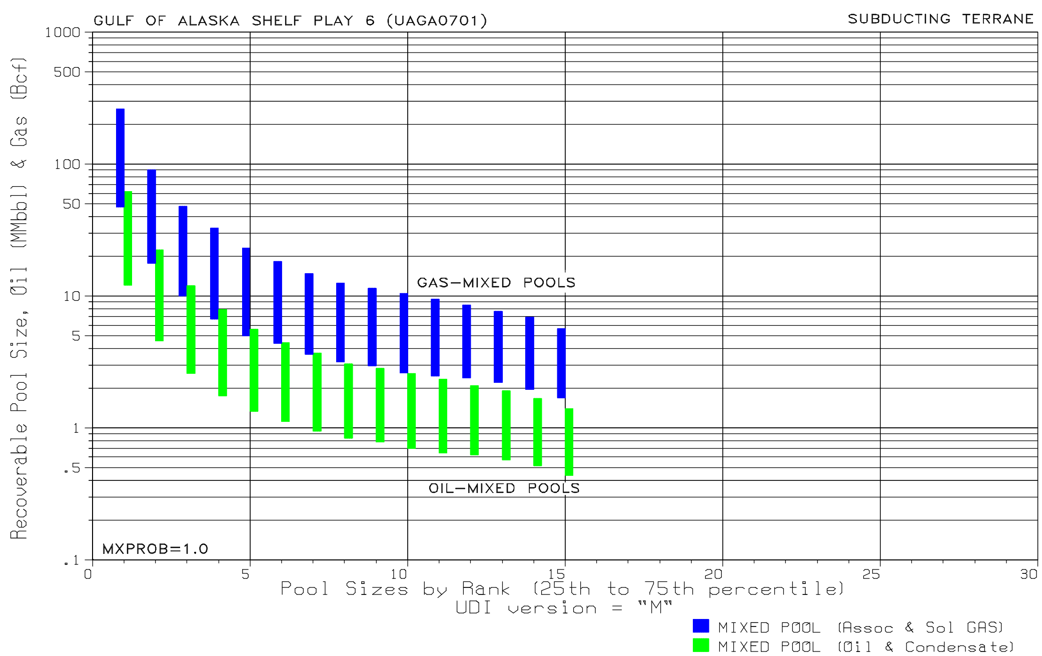


GULF OF ALASKA SHELF PLAY 4 (UAGA0501)			
FRACTILES	**F95**	**MEAN**	**F05**
GAS (TCFG)	**0.000**	**1.967**	**5.397**
OIL (BBO)	**0.000**	**0.308**	**0.778**
BOE (BBO)	**0.000**	**0.658**	**1.711**





GULF OF ALASKA SHELF PLAY 6 (UAGA0701)			
FRACTILES	**F95**	**MEAN**	**F05**
GAS (TCFG)	**0.000**	**0.282**	**0.926**
OIL (BBO)	**0.000**	**0.076**	**0.222**
BOE (BBO)	**0.000**	**0.126**	**0.387**



ECONOMIC RESULTS, GULF OF ALASKA SHELF PROVINCE

(James D. Craig)

INTRODUCTION

This section summarizes the results of economic modeling using the *PRESTO-5* (*P*robabilistic *R*esource *EST*imates-*O*ffshore, version 5) computer program. The economic assessment results are influenced, to a large degree, by the undiscovered, conventionally recoverable oil and gas resources assessed using the *GRASP (G*eologic *R*esource *AS*sessment *P*rogram) computer model. The conventionally recoverable results are discussed in separate .pdf files (*Summaries of Play Results, with Cumulative Probability and Ranked Pool Plots*).

Each province summary page includes three illustrations: (1) cumulative probability plots for risked, conventionally recoverable resource distributions (oil, gas, and BOE); (2) a table comparing risked, mean, conventionally recoverable resources with the risked, mean, economically recoverable resources at current commodity prices; and (3) a price-supply graph displaying economically recoverable resource curves.

The province summary page is followed by a table reporting play-specific, economically recoverable resource estimates for two representative price scenarios: a Base Price scenario ($18/bbl-oil, $2.11/MCF-gas) representing current market conditions; and a High Price scenario ($30/bbl-oil, $3.52/MCF-gas).

PROVINCE SUMMARY PAGE

Risked Cumulative Probability Distributions

The province summary page provides, at page top, cumulative probability distributions for risked, undiscovered endowments of conventionally recoverable oil, gas, and BOE, where resource quantities are plotted against "cumulative frequency greater than %." A cumulative frequency represents the probability that the resource endowment is equal or greater than the volume associated with that frequency value along one of the curves. For example, a 95% probability represents a 19 in 20 chance that the resource will equal, or be higher than, the volume indicated. Cumulative frequency values typically decrease as resource quantities increase. An expanded description of cumulative probability plots is given in "*Summaries of Play Results, with Cumulative Probabilities and Ranked Pool Plots* " provided as a separate .pdf file.

Table of Risked Play Resources

The province summary page provides, at page center, a table comparing the total conventionally recoverable endowment and the smaller quantity of economically recoverable resources that could be profitably extracted under current economic and engineering conditions. Current prices are represented as $18 per barrel of oil and $2.11 per MCF of gas, where gas price is linked to oil price by energy equivalency and discount-value factors (5.62 MCF per barrel; 0.66 value discount). Conventional resource volumes correspond to points on the cumulative probability distributions (at page top). Economic resource volumes correspond to points along the mean price-supply curve (at page bottom). Resources listed as negligible (negl) have volumes lower than the significant figures shown. Not Available (N/A) means that these resources are unlikely to be produced in the foreseeable future because of reservoir conditions or the lack of a viable transportation infrastructure.

The ratio of economic to conventional resources indicates the proportion of the total undiscovered endowment that is profitable to produce under current commodity prices with proven engineering technology. However, for production to occur, commercial discoveries must be made, and the analysis does not imply discovery rates. Given the size and geologic complexity of the offshore provinces, exploration will require extensive drilling, and considering the relatively low chance of commercial success and the high cost of exploration wells, many of these frontier provinces are not likely to be thoroughly tested in the foreseeable future. The ratio of economic to conventional resources should be regarded as an opportunity indicator, rather than as a direct scaling factor for readily available hydrocarbon reserves.

Price-Supply Curves

The province summary page includes, at page bottom, a graph showing price-supply curves representing Low, Mean , and High resource production scenarios. Price-supply curves illustrate how volumes of economically recoverable resources increase as a function of commodity price. Characteristically, increases in commodity price result in corresponding increases in economically recoverable resource volumes. The economic resource volumes represent oil and gas, as yet undiscovered, that could be recovered profitably given the modeled economic and engineering parameters. At very high prices, the mean curve approaches the mean total resource endowment estimated by *GRASP*. The price-supply curves do not imply that these resources will be discovered or produced within a specific time frame, only that the opportunity exists for commercial production at levels controlled by commodity prices.

The price-supply curves were generated by the *PRESTO-5* computer program, which simulates the exploration, development, production, and transportation of pooled hydrocarbons in geologic plays within a petroleum province. Economic viability depends on the interaction of many factors defining the size and location of the hydrocarbon pools, the reservoir engineering characteristics, and economic variables relating expenditures to income from future production streams. The economic simulation is quite complex, owing to the complexities in the state of nature, and requires a sophisticated analytical model.

The following is a brief overview of the *PRESTO-5* modeling process. Geologic parameters (for example, reservoir thickness, pool area, risk) used by the *GRASP* computer model to determine conventionally recoverable resources are transferred into the *PRESTO-5* model through an interface program. Economic viability is determined by performing a discounted cash flow analysis on the expenses and modeled production stream for each pool simulated in a given trial. A Monte Carlo (random sampling) process selects engineering parameters (for example, production rate profiles, well spacing, platform installation scheduling), and cost variables (for example, platforms, wells, pipelines) from ranged distributions. Each simulation trial models the expenses, scheduling, and production for pools "discovered" within a particular play. The sampling process is repeated for productive pools in all geologic plays, and the economic resources are aggregated to the province level. The development simulation process is repeated, typically for 1000 trials, at given set of prices (oil and gas prices are linked). After the specified number of trials are completed for the first set of oil and gas prices, a new set of prices is selected and another round of simulation trials is run. This process continues for approximately 30 iterations, yielding a range of economic resource volumes tied to commodity prices. The results for all runs are given as probability distributions, where selected probability levels can be displayed as continuous price-supply curves.

These analyses determine the resource volumes that are commercially viable under a specific set of current economic and engineering assumptions. No attempt was made to upgrade engineering technology or development strategies that might be implemented in response to higher commodity prices.

The price-supply curves provided in this report are based on the most likely development scenario tailored for each particular province. All provinces were modeled on a stand-alone basis, with engineering assumptions designed for the primary hydrocarbon substance (oil or gas) identified by the *GRASP* analysis. Generally, the secondary hydrocarbon is less economically viable and places an extra burden on the primary hydrocarbon substance. For provinces without existing oil and gas infrastructure, the modeling scenarios were designed assuming that the primary substance would drive initial development in a particular province. Oil-prone provinces were modeled as "oil-only" production, with gas reinjected for reservoir pressure maintenance to maximize oil recovery. Gas-prone provinces were modeled with both gas and oil production because natural gas-liquids (or condensates) are not reinjected. Often the volume of condensates in gas-prone provinces exceeds any volume of non-associated crude oil. All hydrocarbon liquids are commingled in production and transportation systems.

This economic analysis assumes 1995 as the base year. Higher <u>nominal</u> commodity prices in the future (price increases only at the rate of inflation) do not result in higher estimated volumes of economically recoverable resources, whereas higher <u>real</u> commodity prices (increases above the rate of inflation) do increase the economically recoverable resources. The economic model assumes that commodity price and infrastructure costs were inflated equally at an assumed 3% annual inflation rate (flat real price and cost paths). The price-supply curves can be used to project economic resource volumes relative to future price if appropriate discounting back to the 1995 base year is made to account for real price and real costs changes in the intervening years.

The price-supply graph usually contains three curves, corresponding to Low, Mean, and High resource production levels. The Low resource case represents a 95% probability (19 in 20 chance) that the resources are equal to, or exceed, the volumes derived from the price-supply curves. The High resource case represents the 5% exceedance level (1 in 20 chance). The Mean resource case represents the average. In high-cost and high-risk provinces, where there are no economically recoverable resources at the 95% probability level, no "Low" curve is displayed. An apparent anomaly is observed in some cases where the lower tail of the "Mean" price-supply curve indicates economic resources greater than the "High" (5% probability) curve. This situation occurs at low prices where the probability of economic success drops below 5%, and the Mean curve is obtained from the few productive trials occurring at probabilities below 5%.

A few additional observations concerning price-supply curves are noteworthy. Following established convention for price-supply curves, these graphs are rotated from the usual mathematical display of X-Y plots. Although shown along the vertical (Y) axis, price is the independent variable and resource is the dependent variable. In many of the gas-prone basins, price-supply curves will display an abrupt step below which no risked economically recoverable resources are modeled. This step corresponds to the minimum resource value required to overcome the cost of production and transportation infrastructure. Because of the distances to Asian markets, the assumed destination for Alaska gas production, natural gas must be converted to liquid form for transportation by ships. The infrastructure associated with conversion into liquefied natural gas (or LNG) does not lend itself to incremental additions for grassroots projects; therefore, an abrupt "cost-hurdle" created by large LNG and marine terminal installations must be overcome by significant resource volumes.

Finally, the reader must be aware that these price-supply curves are models of risked hydrocarbon resources. Both the geologic risk that the resources are pooled and recoverable as well as the economic risk that development is profitable under the assumed economic and technologic conditions are factored into the reported results. This means that although very low resource volumes are reported as "economically recoverable", these low volumes, in fact, do not correspond to actual quantities of oil or gas. At low prices, risk is dominated by economic factors associated with engineering cost and reservoir performance variables. At high prices, risk is dominated by geologic factors related to volumetric variables. **Risked price-supply curves are most appropriately used to define the comparative potential of petroleum provinces under changing price and probability conditions.** They do not predict the timing of resource discovery or rate of conversion of undiscovered resources to future production. As previously stated, future production of the modeled economically recoverable resources will require extensive exploration programs. In the Alaska offshore, future leasing and exploration activities are likely to be driven by "high-side potential", combining perceptions of greater rewards at higher risk, higher future commodity prices, and innovative technology to reduce costs.

TABLE FOR PLAY RESOURCE DISTRIBUTIONS

The risked mean contribution for each geologic play in the province is tabulated under two hypothetical price conditions. The Base Price ($18 per barrel-oil; $2.11 per MCF-gas) represents current economic conditions. The High Price ($30 per barrel-oil; $3.52 per MCF-gas) represents a situation where real price has increased significantly from current levels. Other economic parameters (for example, discount rate and corporate tax rate) were equal in both scenarios, as were engineering technology and cost assumptions. The play number, name, and *UAI* (*U*nique *A*ssessment *I*dentifier code) provide a link to the data presented in other sections of this report. Hydrocarbon substances are distinguished as oil (includes crude oil and gas-condensate liquids), gas (includes non-associated, associated, and dissolved gas), and BOE (gas volume is converted to barrel of oil equivalent and added to oil volume).

GULF OF ALASKA SHELF MODELING RESULTS

The Gulf of Alaska shelf province was modeled for the production of oil only. Gas resources are not reported in the present economic assessment. This modeling decision was based on two considerations. First, the resources were modeled as associated oil/gas pools (oil reservoirs overlain by gas caps). Second, there is a noticeable negative economic impact on the primary hydrocarbon (oil) if associated gas resources are co-produced. The extra burden is caused by the high cost of liquified natural gas (LNG) processing and transportation infrastructure. Accordingly, the economic assessment assumed that reservoirs in gas caps would not be completed and solution gas separated by topside equipment would be reinjected for reservoir pressure maintenance. Although the emphasis of development in the near future would be oil production, associated gas resources could become available at some future time when oil pools are depleted below a commercial limit.

At present, there is no production and transportation infrastructure for offshore development on the Gulf of Alaska shelf. The development scenario assumed that new infrastructure would be located in Yakutat Bay, including a pipeline landfall, tank farm, and marine export terminal. Produced oil would be delivered to U.S. West Coast ports by tankers from the Yakutat facility. It was assumed that Los Angeles would be the principle receiving port, with route distance from Yakutat of approximately 2200 miles. Because the plays in this province are scattered (generally not overlapping), high development costs were incurred for subsea pipelines to gather produced oil to the central terminal in Yakutat. These gathering lines ranged from 30 to 250 miles in length. Offshore loading was not considered to be feasible because of common, severe storms in the Gulf of Alaska.

Under the Base Price condition ($18 per barrel), the Gulf of Alaska shelf contains 0.05 BBO of risked mean economically recoverable oil, or 8% of the mean conventionally recoverable oil endowment (0.63 BBO). At the High Price condition ($30.00 per barrel), the Gulf of Alaska shelf could hold 0.12 BBO of economic oil, or 19% of the mean oil endowment. If we assume a $30 per barrel price (1995$) and a High resource case (1 in 20 chance), 0.30 BBO of risked economic oil is estimated to be recoverable from this province. This very optimistic model is comparable to the <u>mean</u> economic oil recoverable from the Cook Inlet at <u>current</u> prices (0.27 BBO at $18). The low (8%) ratio between economic and conventionally recoverable oil suggests that most of oil resources occur in small, sub-commercial pools. The lack of economic viability is explained by generally small pool size and high proportions of gas in reservoirs, which cannot support the cost of new infrastructure in the Gulf of Alaska province.

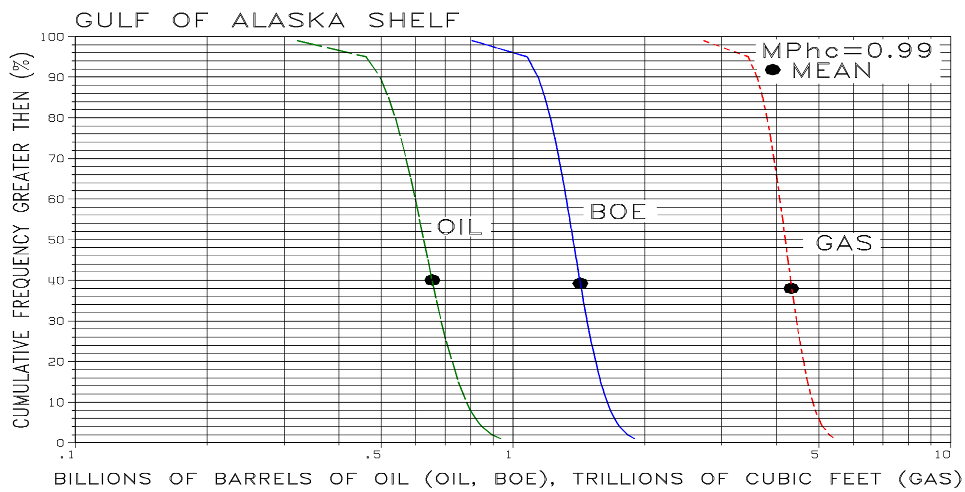
Economic oil resources are expected in 4 of the 5 recognized geologic plays in the Gulf of Alaska shelf province, the exception (Middleton Fold and Thrust Belt, Play 5) being a gas-prone play. However, 70% of the economic resources under the Base Price condition ($18) occurs in Kulthieth Sand play (Play 4). For the High Price condition ($30), 76% of the economic oil resources occur in the overlapping Basal Yakataga Formation (Play 3) and Kulthieth Sands (Play 4) plays.

Previous exploration efforts in the Gulf of Alaska shelf province have concentrated on easily identified structural prospects, and 12 exploration wells failed to discover commercial quantities of oil or gas. Future exploration interest is likely to be driven by expectations of high-side potential (which accepts higher rewards at higher risk), higher future commodity prices, and perhaps improved seismic techniques focused on stratigraphic prospects in plays 3 and 4.

Economic Results for Gulf of Alaska shelf assessment province. (A) Cumulative frequency distributions for **risked, undiscovered conventionally recoverable resources** ; (B) Table comparing results for conventionally and economically recoverable oil and gas; (C) Price-supply curves for **risked, economic oil** at mean and high (F05) resource cases.

BOE, total oil and gas in energy-equivalent barrels; MPhc, marginal probability for occurrence of pooled hydrocarbons in basin; BBO, billions of barrels; TCFG, trillions of cubic feet.

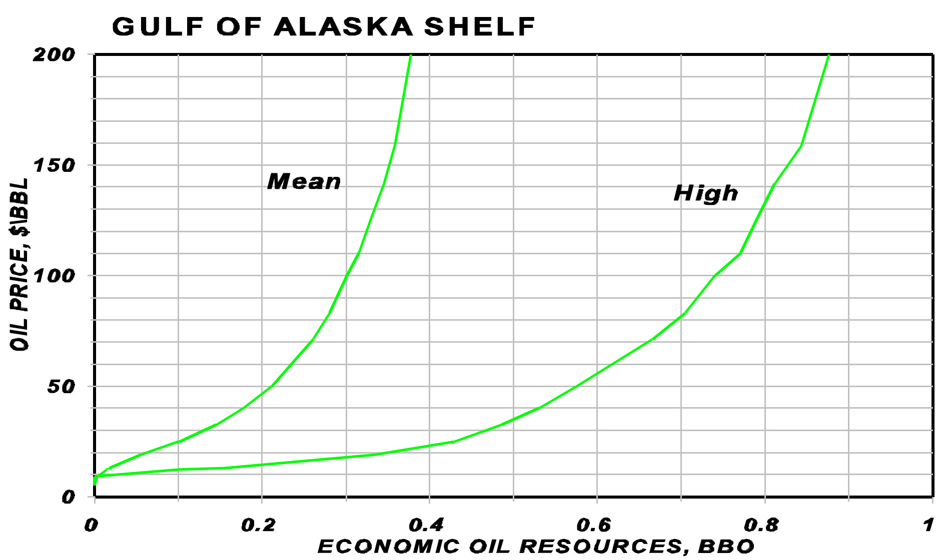
A.



B.

GULF OF ALASKA SHELF PROVINCE		
RESOURCE TYPE	**MEAN OIL (BBO)**	**MEAN GAS (TCFG)**
CONVENTIONALLY RECOVERABLE	**0.63**	**4.18**
ECONOMICALLY RECOVERABLE ($18)	**0.05**	**N/A**
RATIO ECONOMIC/CONVENTIONAL	**0.08**	**N/A**

C.



OIL AND GAS RESOURCES OF GULF OF ALASKA SHELF PLAYS

Risked, Undiscovered, Economically Recoverable Oil and Gas

PLAY NO.	PLAY NAME (UAI * CODE)	BASE PRICE			HIGH PRICE		
		OIL	GAS	BOE	OIL	GAS	BOE
1.	Middleton Fold and Thrust Belt (UAGA0101)	0.000	n/a	0.000	0.000	n/a	0.000
2.	Yakataga Fold and Thrust Belt (UAGA0201)	0.004	n/a	0.004	0.017	n/a	0.017
3.	Yakutat Shelf-Basal Yakataga Fm. (UAGA0401)	0.007	n/a	0.007	0.021	n/a	0.021
4.	Yakutat Shelf-Kulthieth Sands (UAGA0501)	0.032	n/a	0.032	0.069	n/a	0.069
5.	Southeast Alaska Shelf Subbasin	n/e	n/e	n/e	n/e	n/e	n/e
6.	Subducting Terrane (UAGA0701)	0.003	n/a	0.003	0.012	n/a	0.012
	TOTAL	***0.046***	***n/a***	***0.046***	***0.119***	***n/a***	***0.119***

* *Unique Assessment Identifier, code unique to play.*

OIL is in billions of barrels (BBO). **GAS** is in trillion cubic feet (TCF).
BOE is barrel of oil equivalent barrels, where 5,260 cubic feet of gas = 1 equivalent barrel-oil

For direct comparisons among provinces, two prices are selected from a continuum of possible price/resource relationships illustrated on price-supply curves. **BASE PRICE** is defined as $18.00 per barrel for oil and $2.11 per thousand cubic feet for gas. **HIGH PRICE** is defined as $30.00 per barrel for oil and $3.52 per thousand cubic feet for gas. Both economic scenarios assume a 1995 base year, flat real prices and development costs, 3% inflation, 12% discount rate, 35% Federal corporate tax, and 0.66 gas price discount.

Shaded columns indicate the most likely substances to be developed in this province. Economic viability is indicated on price-supply curves which aggregate the play resources in each province.

N/A refers to "not available". Associated gas will be reinjected for pressure maintenance to maximize oil recovery. Coproduction of gas resources severely affects the value of oil resources because of the high costs for LNG infrastructure.

N/E refers to "not evaluated". Play has very high geologic risk.